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**Idiopathic environmental intolerance attributed to  
electromagnetic fields**

**Doctoral dissertation statements**

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## 1. Introduction

*Idiopathic environmental intolerance attributed to electromagnetic fields* (IEI-EMF) – also known as *electromagnetic hypersensitivity* – ‘is characterized by a variety of non-specific symptoms, which afflicted individuals attribute to exposure to EMF’ (WHO, 2005, p. 1). The phenomenon was first described in Scandinavia, where workers worked with visual display units attributed their dermatologic symptoms to these electric equipment (Berg, 1988; Bergqvist, 1984). Afterwards appeared the form of a general syndrome with various non-specific symptoms (mainly concerned nervous system) (Levallois, 2002), also the number of the afflicted countries and the symptom-evoking electromagnetic sources had grown. According to European estimates the prevalence of IEI-EMF is about 4 – 20 % (Carlsson, Karlson, Ørbaek, Osterberg, & Ostergren, 2005; Eltiti et al., 2007). Apart from unpleasant symptoms IEI-EMF also causes high level of distress and could be a severe, disabling condition, which results in loss of job, social isolation and disruption of the ability to conduct normal life functions (Carlsson, Karlson, Ørbaek, Osterberg, & Ostergren, 2005). Specific biomarker pattern characterizing the condition has not been identified so far (Dahmen, Ghezel-Ahmadi, & Engel, 2009; De Luca et al., 2014). Psychological correlates characterizing IEI-EMF are negative affectivity (Hillert, Hedman, Söderman, & Arnetz, 1999), modern health worries, somatosensory amplification (Köteles et al., 2013; Szemerszky, Gubányi, Árvai, Dömötör, & Köteles, 2015), decreased somatic and mental well-being (Carlsson et al., 2005; Österberg et al., 2007) and higher risk of comorbid mental disorders (Frick et al., 2005; Landgrebe et al., 2008; Rubin et al., 2008).

Theories concerning the aetiology of IEI-EMF represent two main lines: while the toxicogenic approach assumes exposure-activated genuine toxicodynamic processes behind the symptoms (Belpomme, Campagnac, & Irigaray, 2015), the psychogenic theories explain the formation of symptoms with psychological processes (e.g. nocebo effect, classical conditioning, biased attention and attribution) (Arnetz, 1997; Devriese et al., 2000; Rubin, Nieto-Hernandez, & Wessely, 2010; van den Bergh, Winters, Devriese, & Diest, 2002). However many authors emphasize the integration of the two approaches, according to them interdisciplinary research groups are needed for the investigation and treatment of IEI-EMF (Brand et al., 2009; Huss et al., 2004).

Double- (or single) blind provocation studies are most frequently used for the investigation of IEI-EMF, where participants are exposed to low level of real electromagnetic fields or sham-exposures in a random manner. Number of correct detections and triggered symptoms are investigated (Rubin, Hillert, Nieto-Hernandez, van Rongen, & Oftedal, 2011;

Rubin et al., 2010). According to the great majority of the provocation studies participants with IEI-EMF cannot detect the exposure more precisely than control subject, also their symptoms are connected to the perceived, and not to the actual presence of exposure (Rubin, Das Munshi, & Wessely, 2005; Rubin et al., 2010). On the other hand interpretation of these results is hindered by methodological deficiencies (e.g. inappropriate exposure conditions, unknown latency (delay between exposure and triggered symptoms) and wash out (required time for symptoms to disappear) periods) (Rubin et al., 2010), and only acute effects of exposure can be examined (Röösli, 2014). Additionally investigations using average values of the IEI-EMF groups do not take into account the fact, that different background processes could be behind the different IEI-EMF cases (Foster & Rubin, 2014). Having regard to all these perspectives a demand has appeared for the qualitative investigations of the aetiology of IEI-EMF apart from the conventional quantitative methods.

According to the current statement of the World Health Organisation (WHO) IEI-EMF is not a medical diagnostic category. Since scientific research has not supported the causal relationship between symptoms and electromagnetic exposure, a new label – *idiopathic environmental intolerance* – was proposed (WHO, 2004). Due to the lack of validated diagnostic criteria, usually the only recruitment criteria applied in IEI-EMF studies is the self-diagnosis, i.e. a single question about whether the symptoms are attributed to EMF by the participant or not. In consequence, there will be a considerable heterogeneity within the IEI-EMF group in the severity of the condition, which leads to inconsistencies between empirical findings (Baliatsas et al., 2012), and also makes more difficult to identify and treat these patients.

Although there is no clear or convincing evidence supporting the toxicogenic background of IEI-EMF, it is undoubted that the symptoms and suffering of the patients with this condition is real (Stenberg et al., 2002). Deeper understanding of the aetiology could facilitate the exploration of the most appropriate therapeutic interventions for this patient group.

### **The aims of the research**

The main aim of our research was to investigate the psychological characteristics of idiopathic environmental intolerance attributed to electromagnetic fields. Additional aim of our work was to implement a novel interdisciplinary investigational method, which eliminates the problems arising about laboratory investigations of IEI-EMF. This method examines

symptom formation processes in real-world and real-time, with environmental, biomedical and psychosocial data collection.

In our first explorative survey study (N = 675, 75.7 % women, age:  $34.52 \pm 13.03$  years) IEI-EMF-related sociodemographic factors and personality characteristics were assessed. Afterwards two experimental investigations were carried out where formation and attribution of symptoms were examined.

In our first experimental investigation IEI-EMF (N = 36) and control (N = 36) subjects were exposed to sham magnetic field provocation setting. We examined the contribution of various body focus related constructs to the dispositional and situational aspects (formation of symptoms, state anxiety) of IEI-EMF in a situation with high perceived risk.

In the second experimental investigation attributional processes were studied. The experiment was based on the classical study of Sachter and Singer (1962). Three groups were applied (placebo pill with sedative information (N = 45), sham magnetic field (N = 43) and control (N = 44)) to investigate the causal attributions concerning cognitive performance and reported symptoms of healthy individuals.

In our experimental investigations changes in physiological arousal (heart rate, heart rate variability, and skin conductance) were also measured.

Three severe IEI-EMF cases were examined with our novel multimodal investigational process. The intensity of electromagnetic exposure, physiological changes (holter ECG) and indicators of subjective psychological and health condition (e.g. symptoms, mood, perceived EMF-exposure, etc.) were recorded parallelly (Ecological Momentary Assessment, EMA). The time series of the measured variables were investigated with separate time series models in order to assess the relationships between physiological measures, real and perceived EMF-exposures and symptoms. In addition laboratory provocation tests were performed so as to investigate the causal relationship between symptoms and exposure under controlled laboratory circumstances. MMPI tests and psychological questionnaires were used for the exploration of potential predisposing and perpetuating psychological characteristics. Multimodal assessments of IEI-EMF could provide us with a more differentiated perspective of the aetiology and facilitate enhanced success in treatment. Case studies performed with three severe IEI-EMF participants will be interpreted along the objectives and not along the hypotheses.

## **Hypotheses**

Our hypotheses were the following:

I. We assumed that the results of previous studies will be confirmed: IEI-EMF will be more common among women, participants with IEI-EMF will score higher on questionnaires assessing psychological characteristics connected to symptom amplification (somatosensory amplification, negative affectivity, subjective physical symptom scale) and symptom attribution (modern health worries). According to our hypothesis the strongest predictor of IEI-EMF will be somatosensory amplification and modern health worries – their effects will last after controlling for negative affectivity.

II. During our first experimental investigation hypothesize we that (II.1.) IEI-EMF participants will show higher level of health anxiety, somatosensory amplification, somatic absorption, negative affectivity and modern health worries. (II.2.) During perceived EMF-exposure higher level of anxiety and symptoms will be reported by IEI-EMF participants, which will be accompany with higher changes in heart rate. (II.3.) According to our hypothesis increase of anxiety, symptoms and heart rate will be predicted by the measured personality characteristics.

III. During our second experimental investigation hypothesize we that (III.1.) both interventions (sham magnetic field, placebo pill with sedative information) will lead to higher level of arousal and symptoms, and (III.2.) deterioration in perceived cognitive performance and appearing symptoms will be attributed to the interventions. In addition we hypothesize that (III.3.) the magnitude of perceived negative effects of the sham magnetic field will be similar to the effect of the placebo pill. (III.4) Positive relationship between attribution tendency and personality characteristics was hypothesized.

## Methods

### Questionnaires

Perceived Stress Scale, PSS (Cohen, Kamarck, & Mermelstein, 1983) (*1. investigation*)

WHO well-being, WHO-5 (Bech, Gudex, & Johansen, 1996) (*1. investigation*)

Somatosensory Amplification Scale, SSAS (Barsky, Wyshak, & Klerman, 1990) (*1., 2., 3., 4. investigation*)

Patient Health Questionnaire Somatic Symptom Severity Scale, PHQ-15 (Kroenke, Spitzer, & Williams, 2002) (*1., 4. investigation*)

Positive and Negative Affectivity Schedule, short, PANAS-s (Watson, Clark, & Tellegen, 1988) Negative Affectivity Scale (*1., 2. investigation*)

Modern Health Worries, MHW (Petrie et al., 2001) (1., 2. 3., 4. investigation)

short Health Anxiety Inventory, SHAI (Salkovskis, Rimes, Warwick, & Clark, 2002) (2., 3., 4. investigation)

Somatic Absorption Scale, SAS (Köteles, Simor, & Tolnai, 2012) (2. investigation)

State Anxiety Inventory, STAI-S (Spielberger, Gorsuch, & Lushene, 1970) (2. investigation)

Groningen Sleep Quality Scale, GSQS, (Mejiman, de Vries-Griever, & de Vries, 1988) (4. investigation)

Minnesota Multiphasic Personality Inventory, MMPI (Hathaway & McKinley, 1942) (4. investigation)

State-Trait Anxiety Inventory, STAI-T (Spielberger et al., 1970) (4. investigation)

Symptom Interpretation Questionnaire, SIQ (Robbins & Kirmayer, 1991) (4. investigation)

### **Physiological measurements**

*Nexus-4* (Mind Media BV, Herten, the Netherlands) device

*Firstbeat Bodyguard 2* (*Firstbeat Technologies Ltd, Jyväskylä, Finland*) mobile ECG device

### **Dosimeters**

*EMDEX PAL* and *EMDEX II* (*Enertech Consultants, Campbell, CA*) personal dosimeters

*Maschek ESM-140* (*Maschek Elektronik, Bad Wörishofen, Germany*) and *Satimo EME SPY 121* (*SATIMO*®, *MICROWAVE VISION S.A.*) personal dosimeters

## **Results and discussion**

I. According to the results of our explorative questionnaire study 8.4 % of the participants (N = 675) could be described with the IEI-EMF definition of WHO. This value is in accordance with the results of previous European survey studies. Our results contradict to previous assessments with regard to the proportion of female gender, as higher rate of females was not found. In accord with our hypothesis participants with IEI-EMF scored higher on questionnaires related to symptom amplification (somatosensory amplification scale, negative affectivity, patient health questionnaire) and symptom attribution (modern health worries). Also the condition was accompanied by lower level of perceived health and well-being and by higher level of stress. Based on the regression analysis somatosensory

amplification and modern health worries predicted IEI-EMF even after controlling for socioeconomic status and negative affectivity. According to the results body-focused attention is an important contributor to IEI-EMF, therefore several different types of body-focused constructs were assessed in our next experimental investigation.

II. In our first experimental investigation participants with IEI-EMF showed higher level of health anxiety, somatosensory amplification, negative affectivity, modern health worries and somatic absorption (II.1. hypothesis). According to the latter results not only fear related monitoring of bodily symptoms discriminate between IEI-EMF and control participants, but also the non-evaluative body focus, namely somatic absorption. This novel finding suggests that higher levels of body focus may not be adaptive in the presence of body symptoms. In accord with previous investigation of our research group IEI-EMF participants reported more symptoms and anxiety in the believed presence of EMF than controls. These differences were not reflected in the assessed physiological variable (heart rate) (II.2. hypothesis). In IEI-EMF group increase of symptoms was connected to health anxiety and state anxiety (II.3. hypothesis). This result especially deserves attention as anxiety-related processes not only direct attention to physical sensations (Barsky & Borus, 1999; Pennebaker, 1994) but also could enhance associative learning (Devriese et al., 2000). According to several authors conditional processes could play an important role in the aetiology of idiopathic environmental intolerances (Berg, Arnetz, Lidén, Eneroth, & Kallner, 1992; van den Bergh et al., 2002) hence anxiety-related psychological characteristics could be particularly important.

III. In the course of our second experimental investigation sham magnetic field and placebo pill interventions did not lead to increase of symptoms or arousal (measured with heart rate and skin conductance) (III.1. hypothesis). One interpretation for the lack of increase of symptoms is that participants were young, healthy individuals and possible harmful effects of the interventions were intentionally not emphasized. Perceived decrease in cognitive performance was attributed to both placebo pill and sham magnetic field, but attribution of symptoms was only present in the placebo group (III.2. hypothesis). Presumably for healthy (non-IEI) participants an ingested agent is more connected to symptoms than the presence of magnetic field. The two interventions did not differ from each other with respect to perceived negative effect of investigation, thus nocebo effect generated by the perceived presence of magnetic field had similar magnitude as placebo pill with sedative information (III.3. hypothesis). According to the results purely attribution-based nocebo effects (in terms of both symptoms and cognitive performance) appeared in

the complete absence of sympathetic activation. This result suggest that the assumption in the literature about nonspecific medication side effects (i.e. the presence of anxiety (arousal) is considered necessary for symptom generation process) is incorrect (Barsky, Saintfort, Rogers, & Borus, 2002; Hahn, 1997; Uhlenhuth et al., 1998). Nocebo effect could appear without physiological changes.

Attribution tendency was positively connected to modern health worries, in other words participants, who reported more concerns were more prone to attribute their perceived decrease in cognitive performance to the interventions (III.4. hypothesis)

IV. Our multimodal investigation made an attempt to develop a comprehensive diagnostic methodology which could facilitate the comprehensive exploration of the background of IEI-EMF and the identification of the adequate treatment.

During the EMA investigation found we statistically significant, although typically weak long range partial effects for 25 out of 78 [subject; physiological measure; EMF] triplets. The effects mostly showed a parasympathetic EMF-related effect which contradict to the main aspect of IEI-EMF (i.e. health damaging effect of EMF, increased arousal due to stress). One cannot rule out the possibility of all these statistically significant partial effects being spurious, resulting from uncontrolled environmental and/or lifestyle factors (e.g. rushing around in a busy urban environment vs. relaxing in a peaceful place in the countryside) which might have a direct causal influence on individuals' physiological functioning and which in turn may be significantly correlated with the intensity of certain EM fields. Controlled laboratory investigations are needed to validate the significant relationships between certain EMF-frequency ranges and physiological variables. In those cases where no connection between exposure and physiological variable was found (70 cases from 78,  $p < 0.005$  significance level) – considering the very large sample size – we can almost certainly exclude the possibility of such a relationship.

The leading complaints were remarkably similar in the three cases. Complaints were predominantly related to ear-sensations (tinnitus, pain, pressing, smarting in and around the ears), and to the area of the head (pain and droning in the head). In the course of EMA performed we low frequency time series analyses to explore how subjectively perceived health symptoms were related to the presence of electromagnetic fields operating at different frequencies. For the vast majority (23 out of 26) of [subject; EMF] pairs we did not found sufficient evidence for EM radiation being in any way related to the intensity of health symptoms. In the three cases where positive results were gained (Participants 1 and 2.:



negative effect of GSM900downlink on symptoms; Participant 3.: positive effect of UMTSdownlink exposure on symptoms) effect sizes were moderate (though non-trivial). Even though several internal and external factors were involved in the time series analysis to control the possible confounding effects (perceived EMF-exposure, hour of the day, mood, activity, social environment, whereabouts, arithmetic averages of physiological data over two consecutive 10-minute intervals preceding the time stamp of each diary entry) we cannot rule out the possibly effects of other, non-investigated factors (problem of third variable). This problem may showed up in the two positive EMF-symptom relationship, where GSM900downlink frequency range (960 MHz, Base to Mobile) had negative partial effect on perceived symptoms of Participants 1 and 2. This beneficial health effect of EMF exposure is incompatible with the concept of electromagnetic hypersensitivity, and could be the result of non-controlled environmental and/or lifestyle factors. A possible explanation is that Participant 1 and 2 lived in the countryside, thus they were exposed to remarkably higher EMFs when they travelled to an urban environment, which, at the same time, might have turned their attention to external stimuli from their bodily signs. On the contrary, UMTS downlink radiation (2110-2170 MHz, Base to Mobile) was positively associated with symptom perception for Participant 3, even after controlling for environmental and subjective factors. Controlled laboratory provocation tests are needed to clearly affirm the causal relationship between exposure and symptoms.

According to the results of double-blind provocation tests participants were not able to detect the presence of EMF-exposure better than chance. Nor were their symptoms or physiological changes connected to the presence of EMF-exposure. But on the other hand we must emphasize, that the elaboration of these provocation studies was solely based on the approved and common methodology available in the literature: the EMF-frequency was chosen based on the perceived sensitivity of participants and the duration of trials and regeneration sessions was determined arbitrarily. In the future these methodological deficiencies will have to be revised.

Our results suggest the importance of a comprehensive psychological investigation in the case of IEI-EMF patients. Our case studies supported the results of the previously presented three investigations, that is several psychological factors lie behind the concept of IEI-EMF: elevated tendency to amplify somatic sensations (in all three cases), to perceive emotional distress as somatic symptoms (somatisation, somatic attribution), and fear of having a serious illness (health anxiety, hypochondriasis) in the case of 1 and 2. These factors could promote the interpretation and labelling of autonomic arousal or even normal

bodily processes as symptoms, and thus contribute to maintenance and biased attribution of symptoms. On the other hand our third participants scored in normal ranges on almost all psychological questionnaires which clearly shows the importance of individual assessments due to the presence distinct psychopathological mechanisms.

Previous life events causing remarkably high psychosocial distress were reported in all cases (e.g. changes in the family structure, identity crisis, loss of social support). Traumas and long-term stressful situations may initiate the chronic activation of physiological stress responses through perseverative cognition (worries, rumination, anticipatory stress) (Brosschot et al., 2005). Sustained stress and arousal may lead to a cognitive-emotional – and presumably physiological – sensitization and distress intolerance of the central nervous system (Brosschot, 2002; Ursin and Eriksen, 2001, 2004). The process could account for symptom formation but do not explain the attribution process. In our first two cases elevated Clinical Scales Paranoia, Psychopathic Deviate, Hypomania, Schizophrenia and high level of Negative Affectivity could lead attentional processes to the possible threatening stimuli, enhance emotional reasoning, and biased information processing, which could lead to selective retrieval of negative memories and drawing invalid conclusions on the basis of the subjective emotional response (Aronson et al., 2001, 2006; Clark, 1999; Mogg and Bradley, 1998; Watson and Pennebaker, 1989). On the other hand the MMPI profile of *Participant 3* was considered as clinically normal.

Notwithstanding that drawing conclusion from three cases is impossible, the results clearly highlight the possibility of different pathomechanisms behind IEI-EMF cases. Hence additional qualitative and/or quantitative measurements are needed beside those researches which investigate the phenomenon on a group-level in order to get a deeper understanding of the aetiology. IEI-EMF seems to be a complicated, multifactorial problem, more than a simple nocebo response related to EMF-exposure.

Multimodal investigation of IEI-EMF has several advantages: it examines the phenomenon from psychological, biological and environmental perspective in parallel. Additional advantage of EMA methodology is the real-world, real-time data collection which maximizes ecological validity, eliminates retrospective bias, and enables us to explore various contextual and situational influences on subjective perceptions. Moreover, it makes possible the simultaneous exploration of a much broader EMF spectrum than the conventional laboratory provocation tests, and also permits the examination of temporal relationships between assessed variables. Nevertheless without controlled laboratory environment the distortional effects of other factors involved in EMF-perception (visual

cues) or symptom formation process (problem of a third variable) cannot be ruled out. So results gained by EMA investigation should be confirmed by controlled laboratory provocation tests. Also a control group with non-IEI-EMF participants should be applied in the EMA investigation. Our future plan is to enhance the validity of our investigational procedure with these methods.

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